

The Residual  $\nu$ -Shift Due to Random  
Skew Quadrupole Errors

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(1)

## The $\nu$ -shift due to the random $a_1$

The random  $a_1$  introduces two coupled modes with  $\nu$ -values  $\nu_1$  and  $\nu_2$ . The  $x$ -motion and the  $y$ -motion now have ~~both~~ both  $\nu$ -values  $\nu_1$  and  $\nu_2$ .

$$x = ( ) e^{i\nu_1 \theta} + ( ) e^{i\nu_2 \theta}$$

$$y = ( ) e^{i\nu_1 \theta} + ( ) e^{i\nu_2 \theta}$$

The  $\nu_1, \nu_2$  can differ <sup>eq.</sup> apprably from the original  $\nu_x, \nu_y$ .

Is this  $\nu$ -shift due to  $a_1$  dangerous?

## Review of the $\nu$ -shift due to random $b$ .

The  $b_1$   $\nu$ -shift is easier to understand.

lines

The resonances  $n_x \nu_x + n_y \nu_y = \text{integer}$   
are considered dangerous

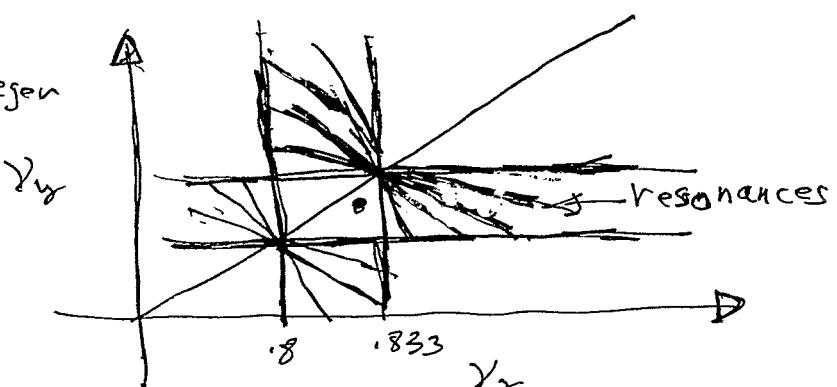
if a time modulation

of the  $\nu$ -values is present:

a  $\nu$ -shift due to  $b_1$ ,

~~which~~ shifts  $\nu_x, \nu_y$

out of the resonance free box is considered dangerous.



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### $\gamma$ -shifts due to $a_1$

In this case the  $\gamma_x, \gamma_y$  diagram is not as useful. I think (~~it is still true~~) that, just as in the  $\gamma$ -shifts due to  $b_1$  case, one needs to avoid the resonance lines  $n_1\gamma_1 + n_2\gamma_2 = \text{integer}$ . This becomes difficult when the shift in  $\gamma_1$  and  $\gamma_2$  becomes comparable to  $33 \times 10^{-3}$ .

The expected  $\gamma$ -shifts in RHIC are

$$|\gamma_1 - \gamma_2|_{\max} \approx 100 \times 10^{-3} \quad \text{for } \beta^* = 6$$

$$|\gamma_1 - \gamma_2|_{\max} \approx 250 \times 10^{-3} \quad \text{for } \beta^* = 2$$

The  $\gamma$ -shifts due to  $a_1$  cannot be corrected with  $b_1$  correctors such as GF and QD.

The  $\gamma$ -shifts due  $a_1$  and  $b_1$  are given by

$$|\gamma_1 - \gamma_2| = 2 \left\{ \left( \frac{\gamma_x - \gamma_y}{2} \right)^2 + |\Delta \gamma_1|^2 \right\}^{1/2}$$

$$\Delta \gamma_1 = \frac{1}{4\pi\rho} \int ds (\beta_x \beta_y)^{1/2} a_1 \exp(i\gamma_x - i\gamma_y)$$

$$\gamma_{av} = (\gamma_1 + \gamma_2)/2 = (\gamma_x + \gamma_y)/2$$

where  $\gamma_x, \gamma_y$  are  $\gamma$ -values when  $a_1 = 0$ .

Above correct to first order in  $a_1$ .

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$b_1$  correctors can be used to move  $\gamma_x, \gamma_y$ .  
 The best one can do is make  $\gamma_x = \gamma_y$  and  
 then  $|\gamma_1 - \gamma_2| = |\Delta\gamma_1|$   
 $\gamma_{av}$  can be controlled using the  $b_1$  correctors.

### Global Correction System

Two families of SKew quadrupoles  
 can be adjusted to make  $\Delta\gamma_1 = 0$ .  
 This should correct the  $\gamma$ -splitting to

$$|\gamma_1 - \gamma_2| = |\gamma_x - \gamma_y|$$

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## Results for the Global Correction System

$$\beta^* = 6$$

N <sub>seed</sub>	Uncorrected		Corrected	
	$\gamma_1, \gamma_2$	$ \gamma_1 - \gamma_2 /10^{-3}$	$\gamma_1, \gamma_2$	$ \gamma_1 - \gamma_2 /10^{-3}$
1	.844, .801	43	.825, .819	6
2	.868, .789	79	.822, .811	11
3	.855, .795	60	.826, .820	6
4	.864, .733	81	.894, .815	9
5	.841, .820	21	.832, .818	14
6	.824, .815	9	.828, .820	8
7	.836, .818	18	.830, .822	8
8	.872, .772	100	.820, .805	15
9	.845, .805	40	.826, .821	5
10	.854, .811	43	.827, .821	6

$$\beta^* = 2$$

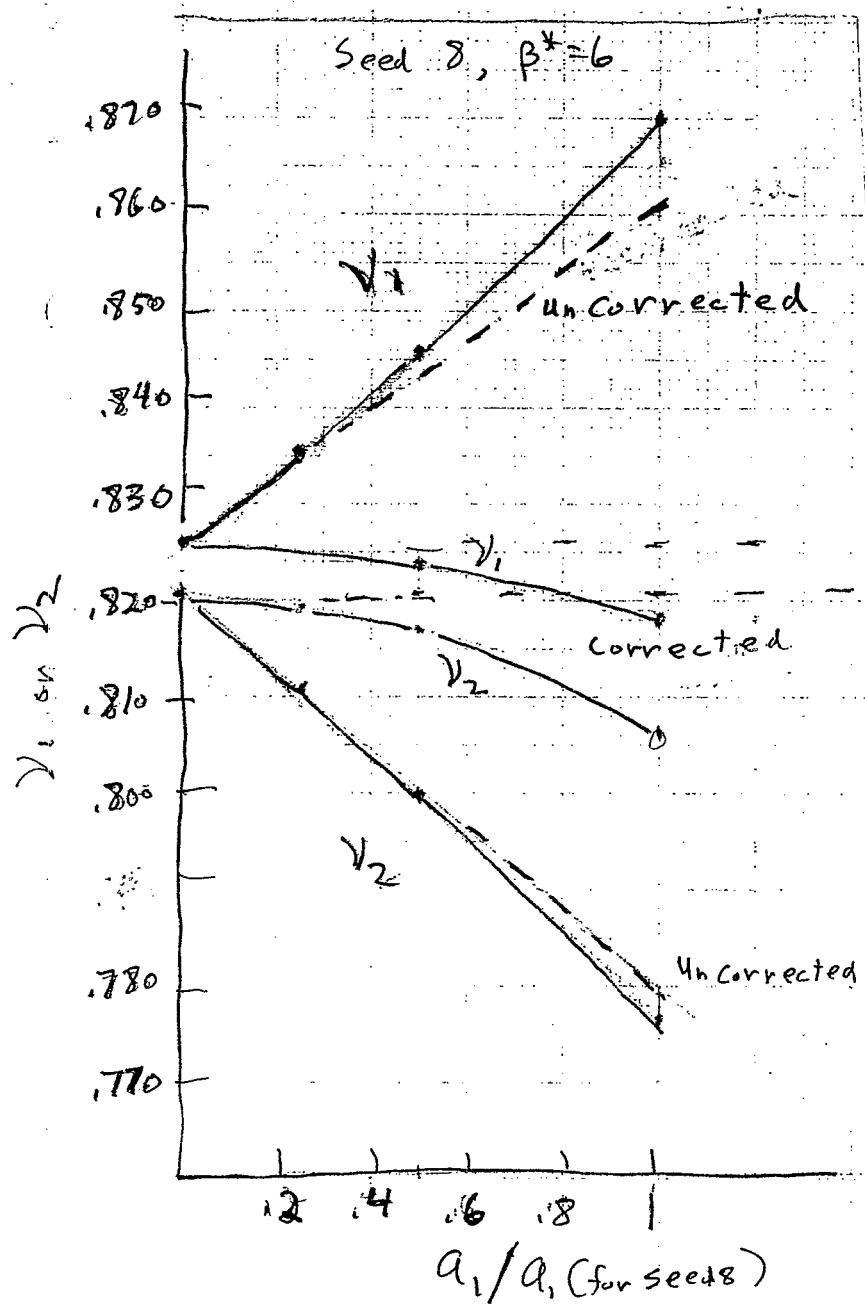
N <sub>seed</sub>	Uncorrected		Corrected	
	$\gamma_1, \gamma_2$	$ \gamma_1 - \gamma_2 /10^{-3}$	$\gamma_1, \gamma_2$	$ \gamma_1 - \gamma_2 /10^{-3}$
1	.854, .796	58	.828, .822	6
2	.935, .707	228	.838, .819	19
3	.869, .783	86	.829, .825	4
4	.883, .772	111	.830, .823	7
5	.872, .778	94	.836, .826	16
6	.848, .805	43	.832, .821	11
7	.847, .840	7	.852, .834	18
8	.895, .741	154	.838, .818	20
9	.866, .785	81	.828, .822	6
10	.891, .749	142	.827, .822	5

In a fair number of machines, there is a large residual  $|\gamma_1 - \gamma_2|$ . In 3 cases for  $\beta^* = 6$  and for 5 cases for  $\beta^* = 2$ , the residual  $|\gamma_1 - \gamma_2|$  is about  $11 \times 10^{-3}$  to  $20 \times 10^{-3}$ .

This appears to be due to terms in  $|\gamma_1 - \gamma_2|$  which go like  $a_1^2$  or higher powers of  $a_1$ .

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$\gamma_1, \gamma_2$  versus  $a_1$



## Local Correction System

If appears that the correction of the residual  $(\gamma_1 - \gamma_2)$  requires a more local correction system.

A possible local correction is the  $a_i$  correctors near QD in the arcs.

Using these correctors, assuming each  $a_i$  corrector can be individually powered, the following  $(\gamma_1 - \gamma_2)$  was achieved

$$\beta \alpha = 6$$

Need	Global Correction	Local Correction
	$ \gamma_1 - \gamma_2 /10^{-3}$	$ \gamma_1 - \gamma_2 /10^{-3}$

8	15
5	13
2	10

$$\beta^* = 2$$

8	20	7.2
7	18	7.5
6	11	6.8
5	16	4.0
2	19	7.5

Further correction could be achieved by making  $\gamma_x = \gamma_y$  using  $b_i$  correctors.

## Some Unsolved Problems

- 1) How well can 4-families of  $\alpha, \beta$  correctors per sextant do?
- 2) What measurements can one do to help set the local  $\alpha, \beta$  correctors?
- 3) Can one correct the residual  $(\lambda_1, -\lambda_2)$  and the reduction in AsL due  $\alpha, \beta$  simultaneously with the same  $\alpha, \beta$  correctors.